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ACIDIC PRECIPITATION IN ONTARIO STUDY

EMISSION INVENTORY OF ONTARIO AND EASTERN NORTH AMERICA DURING 1980-1983 WITH EMPHASIS ON THE SUDBURY SHUT-DOWN PERIOD

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Project Co-ordinator: Dr. T. Brydges

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Meteorological studies to
quantify the effects of Sudbury
emissions on precipitation
quality and air quality during

77515

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Synopsis

SO_2 emissions over eastern North America declined from about 24.5 million tonnes in 1980 to 22.6 million tonnes in 1982. This decrease is attributed to utility emission reductions in eastern U.S. and smelter reduction in eastern Canada. For regions south of the Great Lakes, SO_2 emission decreases were in excess of 1 million tonnes. In Canada, the most significant decrease occurred in Ontario, approximately 0.6 million tonnes (0.5 million tonnes in the Sudbury area). In contrast, NO_x emissions over eastern North America remained relatively constant or declined marginally since 1980 (14.3 million tonnes in 1980 to 14.1 million tonnes in 1982).

Seasonal variations in SO_2 emissions in Ontario, adjacent provinces, and neighbouring states indicate the uniqueness of conditions in Ontario during the Sudbury smelter shut-down period (July 1982 - March 1983).

Emission Inventory of Ontario and Eastern North America During 1980-1983 With Emphasis on the Sudbury Shut-Down Period

1. Introduction

In eastern North America, man-made emissions of sulphur dioxide (SO_2) and oxides of nitrogen (NO_x) are implicated in the increase in acidity of precipitation. Anthropogenic activities, primarily utility combustion, ore smelting and transportation, result in large quantities of these sulphur and nitrogen compounds being emitted into the atmosphere. These compounds subsequently undergo long-range transport and transformation, and eventually cause acidic precipitation. As a consequence, acidic deposition may occur over areas a great distance from the source regions of these sulphur and nitrogen compounds.

The cause and effect relationship between emissions and precipitation acidity is by no means conclusive. While it is generally believed that abatement measures of SO_2 and NO_x emissions in eastern North America are necessary to effectively reduce the acidity of precipitation, there remains uncertainty as to exactly how much emission reductions are required in order to prevent further damage to the environment. Examination of emission variations and precipitation acidity may shed some light on this particular question.

As part of such a study, this paper provides background information on the magnitude and distribution of SO_2 and NO_x emissions over eastern North America, both spatially and temporally, for the years 1980-1983 for which precipitation acidity data are available. The period of the Sudbury smelter shut-down (July 1982 - March 1983) when SO_2 emissions in Ontario declined substantially is emphasized. It should be noted that this paper does not attempt to analyse the emission changes nor to relate the changes to deposition.

2. SO_2 and NO_x Emissions in Eastern North America

A. SO_2 Emissions

The total SO_2 emissions for eastern North America for the year 1980 are estimated to be 24.9 million tonnes, with the ratio of U.S. to Canadian emissions at 5.4 to 1 (U.S. - 21.0 million tonnes and Canada 3.9 million tonnes). Thermal power plants are the primary source and contributed about 63% of the total emissions. For the eastern U.S., approximately 71% of the SO_2 emissions came from utilities, the highest density of which occurs in the upper Ohio River Valley Region. In contrast, for eastern Canada approximately 58% of the SO_2 emissions came from six copper-nickel smelters (two of which are located in each of the Provinces - Manitoba, Ontario, and Quebec), and one iron ore processing operation in Ontario. Power plants contributed only 15% of the SO_2 emissions in eastern Canada and these are primarily located in Southern Ontario.

Since 1980, SO_2 emissions in eastern North America have shown an overall small decline. Preliminary estimates are 24.2 million tonnes (U.S. - 20.5 million tonnes and Canada 3.7 million tonnes) for 1981, and 22.6 million tonnes (U.S. - 19.5 million tonnes and Canada 3.1 million tonnes) for 1982 (Table 1). This represents a 9% decrease (2.3 million tonnes) in SO_2 emissions from 1980 to 1982 and is largely a result of utility emission reduction in eastern U.S. (1.5 million tonnes and significant smelter reduction in eastern Canada (0.8 million tonnes).

Figure 1 shows the changes in SO_2 emission levels on a state and provincial basis between the years 1980 and 1982. Over eastern United States, decreases in SO_2 emissions for the regions south of the Great Lakes were in excess of one million tonnes. Five states, namely, Alabama, Indiana, Kentucky, Pennsylvania and Tennessee had SO_2 emission decreases in excess of 100,000 tonnes each, and their combined total decrease was 976,000 tonnes. For the remaining eastern states, there was an overall decline in SO_2 emissions as well. For eastern Canada, significant decreases occurred in Ontario and Manitoba (a combined total decrease of 792,000 tonnes), largely a result of decline in smelter activities. The reduction in Ontario, 595,000 tonnes SO_2, was the most striking and was primarily caused by the Sudbury smelters shut-down during the last six months of 1982. SO_2 emissions in the Sudbury area was estimated to be 935,000 tonnes in 1980 and 389,000 tonnes in 1982, a decrease of 546,000 tonnes.

B. NO_x Emissions

For eastern North America, NO_x emissions in 1980 are estimated to be 14.3 million tonnes (U.S. - 13.2 million tonnes and Canada - 1.1 million tonnes) with the ratio of U.S. to Canadian emissions at 12.0 to 1. The primary NO_x emission source in both eastern U.S. and Canada is the transportation sector (46% in the U.S. and 62% in Canada). NO_x discharges from power plants contributed 36% to the total NO_x emissions in eastern U.S. and about 15% to eastern Canada total. Geographically, the highest density of NO_x emissions come from the urbanized areas of New York/New Jersey, Chicago, Detroit/Toledo in the U.S, and from Toronto and Montreal in Canada.

Since 1980, NO_x emissions in eastern North America are believed to have been relatively constant or to have declined marginally. Preliminary estimates are 14.3 million tonnes in 1981 and 14.1 million tonnes in 1982 (Table 1). This represents approximately a 1% decrease (0.2 milion tonnes) in NO_x emissions between 1980 and 1982, and is largely the result of NO_x utility emission reductions in eastern U.S. In the estimates for 1981 and 1982, it is assumed that emissions from the transportation sector in the U.S. were unchanged from 1980. This would tend to cause an overestimate of the NO_x totals for 1981 and 1982 as there are suggestions of decrease in NO_x from transportation due to the energy crisis and the shift to more fuel-economy cars.

In view of the suspected small changes in NO_x emissions since 1980 and the prevailing thinking that SO_2 emissions are probably a far more important cause of the acid precipitation problem than NO_x, the remaining sections of this study will be directed to the characterization of SO_2 only.

3. SO_2 Emissions In Ontario: 1980-1983

In 1980, SO_2 emissions in Ontario were about 1.7 million tonnes, contributing 44% to the total SO_2 emissions in eastern Canada. The SO_2 emissions emanated from three main source sectors-smelters (55%), utilities (23%), and iron ore processing (9%) and were largely the result of six major point sources. SO_2 emission levels decreased slightly in 1981 to 1.6 million tonnes and was followed by a stronger decline in 1982 to 1.1 million tonnes as the Sudbury smelters were essentially not in operation during the latter half of the year. As a result, utilities became the dominant emission source sector in 1982, contributing about 40% to the Ontario SO_2 total. The smelter sector was next at 35% and iron ore processing contributed 6%. In 1983, the shut-down of the smelters persisted through the first quarter of the year. By the second quarter, SO_2 emissions had begun to rise with the smelter emissions once again the dominant source contributor to the total SO_2 emission of Ontario.

4. Seasonal Variation in SO_2 Emissions

Figure 2 shows the seasonal variation in SO_2 emissions for Ontario and its major source sectors for the period January 1980 to June 1983 and encompassing the Sudbury smelter shut-down period (July 1982 - March 1983). As can be seen, the seasonal variations in the total Ontario SO_2 emissions are generally sensitive to the seasonal operating schedules of the Sudbury smelters. For 1980, the seasonal variation for the province as a whole (expressed in percentages by quarters) were small (29-24-22-25) with a difference of only 7% between the highest and lowest quarter. The situation in 1981 was somewhat similar, being characterized by relatively small changes in seasonal SO_2 emissions (27-26-19-28). In contrast, the seasonal variability in total SO_2 emissions in 1982 was quite pronounced (45-27-13-15) with a difference of 32% between the highest and lowest quarterly emissions. It is to be noted that only 28% of the total SO_2 emissions in Ontario for 1982 occurred during the latter six months when the Sudbury smelters were not in operation. Ontario SO_2 emissions (for the period July-December of each year) were 799,000 tonnes in 1980, 758,000 tonnes in 1981, and 305,000 tonnes in 1982. For these same years and season, the Sudbury smelter emissions were 421,000, 369,000, and 13,000 tonnes respectively.

In order to assess the potential impact of this marked seasonal variation in Ontario emissions, it is necessary to consider the seasonal SO_2 emission characteristics of neighbouring provinces and states during the same period. Because of data availability, only the period 1980 to 1982 was examined with emphasis on the combined third and fourth quarters emissions of these respective years. Such data are given in Table 2. With the exception of Ontario, it is apparent that the SO_2 emissions (expressed as a percentage of the annual total) for the last half of each year are consistent from year to year (less than 4% variability). For Ontario, however, the impact of the Sudbury smelter shut-down on emissions is evident. Only 28% of Ontario's emissions occurred in the latter half of 1982, as compared to 47% in 1980 and 1981. In terms of emission quantity on a state or provincial basis, it is also evident that the most significant change occurred in Ontario in 1982. For the period July - December, Ontario SO_2 emission decreased 481,000 tonnes (60%) from 1980 to 1982. During this same period, marked emission decreases occurred south of the Great Lakes, particularly in Pennsylvania, Indianna, Tennessee, Ohio, and Kentucky. These five states showed an overall decrease of 613,000 tonnes SO_2. Such emission variations must be considered in evaluating the acidity of precipitation during these years. It is important to recognize also that these emission variations are only a small fraction of the total amount of SO_2 that are typically emitted in the area south of the Great Lakes.

5. Summary

An examination of SO_2 and NO_x emissions in Ontario and eastern North America during the period 1980-1983 indicates:

1. SO_2 emissions over eastern North America have declined from 24.9 million tonnes in 1980 to 22.6 million tonnes in 1982, a decrease of 9%. This decrease is attributed to utility emission reductions in eastern U.S. and smelter reductions in eastern Canada. For regions south of the Great Lakes, SO_2 emissions decreases were in excess of one million tonnes. In Canada, the most significant decrease occurred in Ontario, approximately 0.6 million tonnes (0.5 million tonnes in the Sudbury area).

2. NO_x emissions over eastern North America have been relatively constant or have declined marginally since 1980 (14.3 million tonnes in 1981 and 14.1 million tonnes in 1982).

3. SO_2 emissions in Ontario, a dominant contributor to the emission in eastern Canada, emanate primarily from smelters, utilities and iron ore processing. The smelters are by far the most dominant, so much so, that the total SO_2 emissions in Ontario are sensitive to the operating schedule of these sources. The recent Sudbury smelter shut-down (July 1982 - March 1983) resulted in drastic emission declines in Ontario. For example, only 28% of the total SO_2 emissions in Ontario in 1982 occurred during the latter six months when the Sudbury smelters were not in operation.

4. The seasonal variations in SO_2 emissions in Ontario, adjacent provinces, and neighbouring states indicate the uniqueness of conditions in Ontario during the Sudbury smelter shut-down period. It must, however, be recognized that large SO_2 emission reductions were occurring simultaneously over areas south of the Great Lakes. For example, Ontario SO_2 emissions (July - December) decreased 481,000 tonnnes (60%) from 1980 to 1982 while at the same time Pennsylvania, Indiana, Tennessee, Ohio, and Kentucky showed an overall decrease of 613,000 tonnes.

5. In terms of quantity,it should be noted that there are a number of nearby states that emit similar or more quantities of SO_2 than Ontario. Emission changes in one area, for example Ontario, would tend to be masked in the overall emission picture.

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TABLE 1

SO_2 & NO_x Emissions in Eastern North America

(thousands of metric tons)

	1980		1981		1982	
	SO_2	NO_x	SO_2	NO_x	SO_2	NO_x
eastern U.S.	21.0	13.2	20.5	13.2	19.5	13.0
eastern Canada	3.9	1.1	3.7	1.1	3.1	1.1
eastern N.A. (total)	24.9	14.3	24.2	14.3	22.6	14.1

TABLE 2

SO_2 Emissions for the July-December Period During 1980-1982

(thousands of metric tons)

	1980		1981		1982			
PROVINCE/STATE	SO_2	(%)*	SO_2	(%)*	SO_2	(%)*	Difference in SO_2 1982-1980	(%)
ONTARIO	799	(47)	758	(47)	318	(28)	-481	(-60)
MANITOBA	196	(40)	169	(39)	156	(42)	-30	(-20)
QUEBEC	579	(50)	579	(50)	552	(50)	-27	(-5)
Major State contributions								
ILLINOIS	688	(50)	665	(52)	654	(50)	-34	(-5)
INDIANA	874	(51)	822	(50)	748	(50)	-126	(-14)
KENTUCKY	536	(50)	517	(49)	450	(47)	-86	(-16)
MISSOURI	617	(51)	620	(53)	631	(54)	+14	(+2)
NEW YORK	505	(50)	497	(48)	504	(50)	-1	(- 1)
OHIO	1312	(52)	1228	(48)	1203	(48)	-109	(-8)
PENNSYLVANIA	1109	(52)	1011	(52)	942	(49)	-167	(-15)
TENNESSEE	513	(50)	485	(50)	388	(52)	-125	(-24)
W. VIRGINIA	514	(48)	513	(50)	469	(48)	-45	(-9)
Other Selected States								
MICHIGAN	397	(50	418	(50)	414	(51)	+17	(+4)
MINNESOTA	120	(47)	111	(49)	93	(46)	-27	(-23)
WISCONSIN	291	(48)	281	(49)	265	(50)	-26	(-9)
EASTERN U.S.	10,698	(51)	10,354	(50)	9,772	(50)	-926	(-9)

* % of annual total.

SULPHUR DIOXIDE EMISSION CHANGES BETWEEN 1980 AND 1982 IN EASTERN NORTH AMERICA (THOUSANDS OF METRIC TONS)

+ INCREASE
- DECREASE

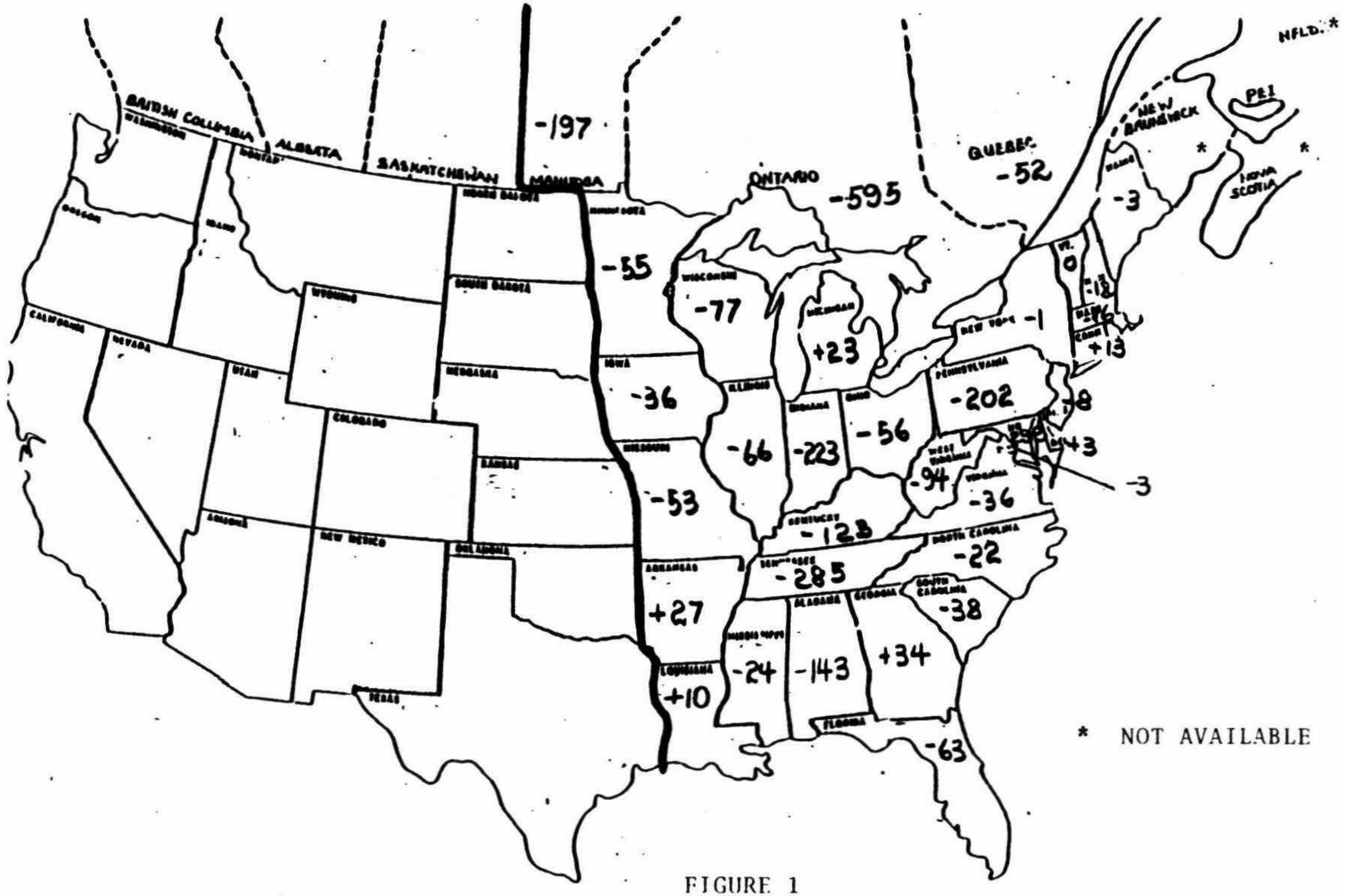
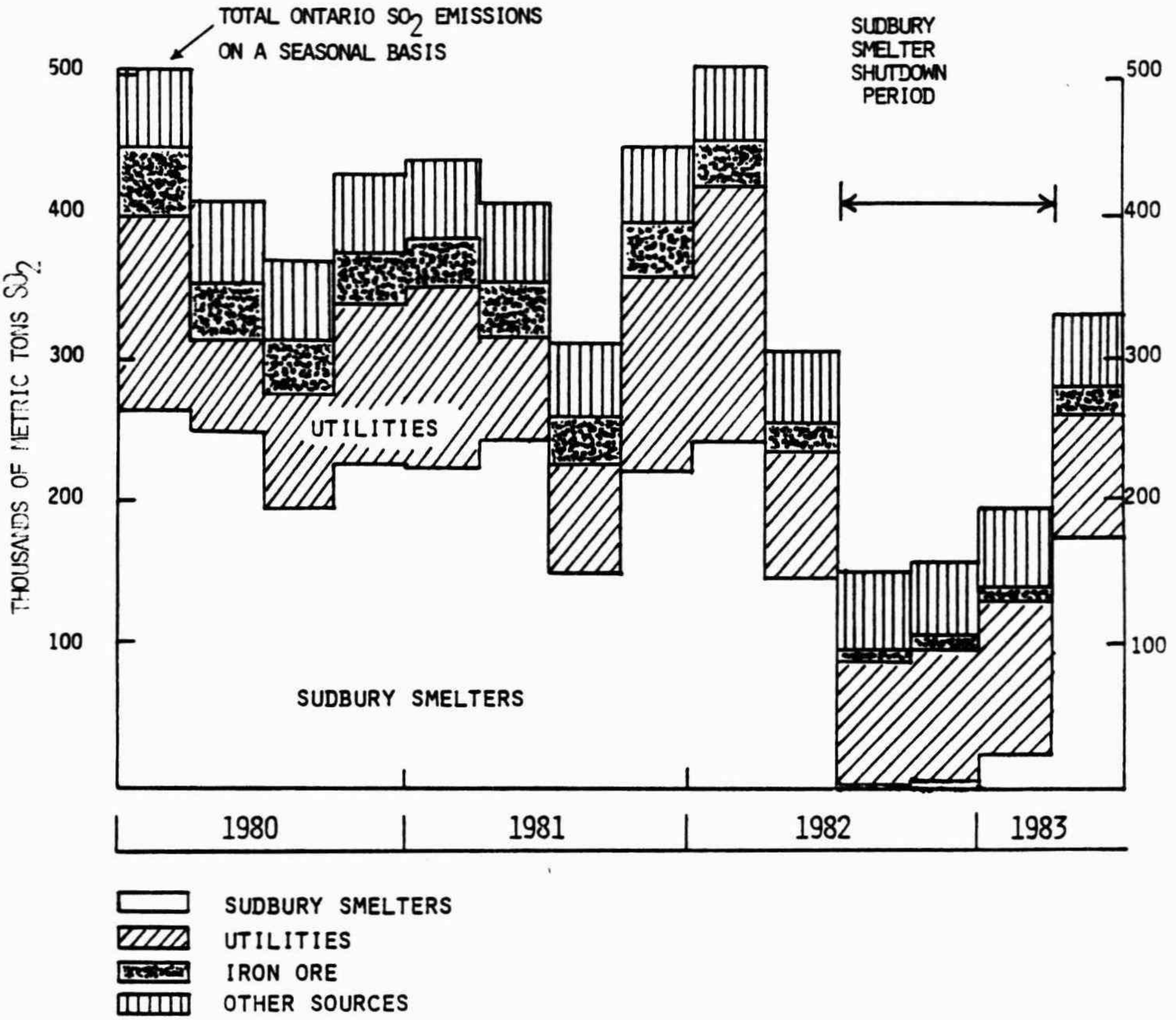


FIGURE 1



SEASONAL VARIATION IN THE SO_2 EMISSIONS IN ONTARIO
FOR THE PERIOD JAN. 1980 - JUN. 1983

FIGURE 2

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